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DROUGHT OF 1976-77

CENTRAL VALLEY, CALIFORNIA

by

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ABSTRACT

This study examines the economic effects of the 1976-77 California Drought with emphasis on the Central Valley. 1976-77 was the driest two-year period in California's recorded weather history and severe economic losses were expected. But increased use of groundwater and reallocation of surface water by farmers and State and Federal authorities reduced the effects on crop yields. Also, prices of farm products rose because of lower production. So that, while individual farmers were adversely affected, net farm income was more than $2.5 billion, only 9% below the record high income of $2.8 billion in 1974.

KEY WORDS: California Central Valley, San Joaquin Valley, San Joaquin Basin, Tulare Basin,Sacramento Basin, Delta-Central Sierra, State Water Project, Central Valley Project, drought analysis, linear programming, applied irrigation water, irrigated crop sector, ground water overdraft.

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SUMMARY

California was the western state most adversely affected by the 1976-77 drought, the State's driest two-year period in the past century. This study examines the economic impact of the drought on irrigated agriculture in the Central Valley, the area of the State in which the drought's effects were the most pronounced. The drought peaked in 1977 but was effectively broken in February 1978 following abnormally high precipitation across the State.

In 1976, the statewide economic effect of the drought was estimated to be $510 million. By early 1977, Federal and State officials concluded that the drought was continuing, and that the social and economic implications would be much more far-reaching than in 1976. Drought task forces were organized at the national, regional, and state level to initiate cooperative actions to mitigate drought effects and to evaluate the economic effects of the drought.

This report presents the analysis made by the Food and Agriculture Subcommittee (FAS) of the California Governor's Drought Emergency Task Force. Most of the report deals with the irrigated sector of the Central Valley, but a brief discussion of the statewide analysis is presented.

Economic losses due to the drought were much less severe than expected, primarily because of the effectiveness of mitigating actions of individuals and agencies, and higher

than expected farm prices. The mitigating actions included record increases in ground water pumping, negotiated transfers of water between contractors, water conservation measures, and shifts to crops requiring less water.

Although many individual Central Valley farmers undoubtedly suffered from the drought in 1977, irrigated crop farmers as a group were estimated to be somewhat better off than if there had been no drought. The same pattern was observed at the State level, as evidenced by the fact that net farm income in 1977 was the second highest on record. The primary reason for this was that irrigated crop yields and prices were higher than normal and more than offset acreage reductions and shifts to less profitable crops.

The study points out the need for an ongoing analytical capability and data base, coupled with a responsive information system. The development of this capability would permit policy analysts to provide decision-makers with timely evaluation of resource problems such as the drought. It would also prevent overly pessimistic or optimistic evaluations which result from inappropriate perceptions of rapidly changing conditions.

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INTRODUCTION

The State of California is the Nation's leading state in farm cash receipts, accounting for 9% of total U.S. farm cash receipts in 1979. In that year, California led the Nation in production of 48 commercial crop and livestock commodities.

The Central Valley, containing over 1/3 of the State's area, is California's most productive agricultural region (Figure 1). The Central Valley contains four hydrologic areas: the Sacramento, the San Joaquin, the Tulare, and the Delta-Central Sierra Basins. The Central Valley contains about 75% of the State's 8.7 million acres of irrigated land. The San Joaquin Basin contains Fresno County, the Nation's leading agricultural county, with $1.7 billion in farm sales in 1979. In that year, farm sales exceeded $1 billion in two Tulare Basin counties, Kern and Tulare. Total cash receipts from farm marketings in California were $12.1 billion in 1979.

The Central Valley floor has warm, dry summers and mild winters with relatively light rainfall. Average annual rainfall declines steadily from north to south, with an average of 23 inches at Red Bluff in the north to 6 inches at Bakersfield in the south. The Sierra Nevada Mountains on the east and the Coast Range on the west have much heavier precipitation. As on the Valley floor, precipitation in the mountains declines as one goes from north to south. For example, the

mountains near Chico in the north have an average precipitation of 80 inches, as compared with 35 inches in the elevated area east of Bakersfield (10).1/

The California drought gradually developed over time, beginning in May 1975 with below normal precipitation. It was recognized as a major problem beginning in early 1977. Responsible agencies and officials began to be concerned about the need for immediate policy actions to prevent detrimental economic and social effects. A summary history of the drought is presented in Appendix A.

Year to year precipitation in the Central Valley Basin varies widely. The maximum recorded annual runoff is more than seven times the minimum. The longest recorded drought period since 1850 was from 1928-34, but researchers evaluating tree rings have estimated that earlier drought periods may have lasted as long as 20 years (2).

Two criteria are now used by California to define a critical dry year or drought condition. One criterion is based on records of annual natural inflows into Shasta Lake, and the other is based on records of total accumulated inflows to the lake over several years. The 1977 water year2/ qualified as a critical dry year on both criteria.

1/ Underscored numbers in parenthesis refer to references listed at the end of the report.

2/ The water year is defined by the State of California as the period from October 1 of one year to September 30 of the next year.

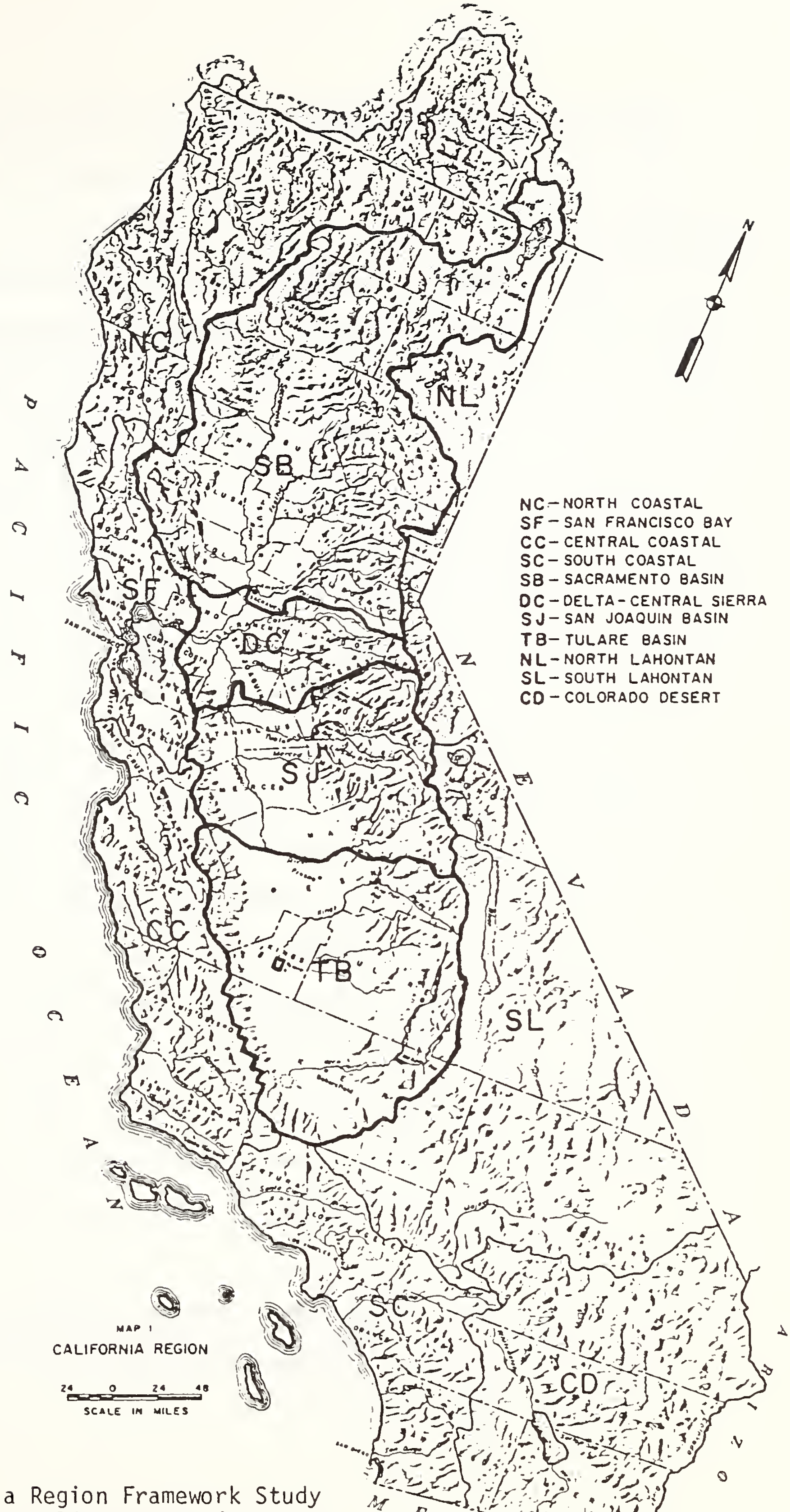

Fig. 1 California Region Framework Study Committee, California Region, Comprehensive Framework Study, Appendix XII, Recreation, June 1971 Map 1.

ORGANIZATION OF DROUGHT EVALUATION AND ASSISTANCE

Inception

Drought evaluation was initiated in early 1977 at the Federal, regional, and state level with the organization of a USDA task force. This task force provided a March 1977 report to the U.S. Senate Committee on Agriculture, Nutrition and Forestry.1/ At the regional level in the West, 23 states worked through an ad hoc Western Regional Drought Action Task Force. The Western Governors' Policy Office (WESTPO) and the Western States Water Council provided staff support to the Task Force.

In California, several task forces were formed to assemble available information and to mobilize the resources from the various agencies into a cohesive action program. The two primary task forces relating to the agricultural sector were the Governor's Drought Emergency Task Force (DTF) and the Interagency Agricultural Information Task Force (IAITF).

The DTF included representatives from the various State departments, including the Department of Water Resources (DWR), Department of Food and Agriculture (DFA), Department of Forestry, the Water Resources Control Board, the Office of

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1/ U.S. Dept. of Agriculture. Impacts of Weather, Farming, Forestry, and People. Prepared for the U.S. Senate Committee on Agriculture, Nutrition, and Forestry. March 31, 1977.

Emergency Services, the Public Utilities Commission, Department of Energy Resources, the Conservation and Development Commission, and the National Guard. The State's National Guard commander, Major General Frank J. Schober, Jr., was appointed director of the DTF. Four Federal agencies participated directly in the DTF, including the USDA's Soil Conservation Service (SCS), Bureau of Reclamation (BuRec), the Army Corps of Engineers, and the Geological Survey. Other DTF participants included the University of California, the Farm Bureau Federation, the Association of California Water Agencies, and the Pacific Gas and Electric Company (PG&E).

The individual agencies participating in the DTF also organized their own drought evaluation activities. The DWR industrial outlooks study staff redirected its activities toward forecasting the potential economic impacts of the drought. The DFA formed its own subcommittee to assist in the analysis of crop changes, reduction of crop acreages, and other drought-related agricultural effects.

The IAITF was organized for the twofold purpose of: 1) developing and disseminating information to aid farmers in their 1977 planting decisions, and 2) providing an ongoing source of information for prudent irrigation management and other related agricultural problems. Like the DTF, the IAITF also formed a number of subcommittees staffed with knowledgable specialists. The Federal agencies participating in the IAITF included the SCS, BuRec, the Geological Survey, and the

Agricultural Research Service (ARS). The State departments included DWR, DFA, the Water Resources Control Board, and the Division of Mines and Geology. The other participating agencies included the University of California (UC) at Davis, UC Extension Service, the Farm Bureau, and PG&E.

Drought Task Force Role

The DTF received the bulk of the media attention throughout the drought. On March 7-8, 1977, the DTF sponsored the Governor's Drought Conference in Los Angeles (13). This conference focused state, regional, and national attention on the California drought. It brought a number of experts together to share their knowledge and insights with each other and displayed the State's commitment to finding solutions to the problems caused by the drought. The conference also displayed the extent of shortcomings in the area of data and analytical capability for evaluating the drought.

The DTF helped initiate legislative proposals at the national, regional, state, and local levels. At the national level, it presented testimony before several Congressional groups, including the House Committee on Small Business. The DTF also conducted briefings for the California Congressional delegation. At the regional level, DTF met with the Western Regional Drought Action Task Force.

At the state level, the DTF conducted five regional conferences to gather drought information and to provide a

forum for public input on ways to solve local problems. DTF worked closely with the California Legislature in drafting legislative proposals, providing briefings, and testifying before legislative committees, including a joint hearing before the Assembly Agriculture and Water committees. The DTF was active in the educational area as well. Task Force members served as speakers, made presentations to community water resource management workshops, and developed and released a directory of State-agency drought assistance responsibilities.1/ In the analytical area, the DTF cooperated with the DFA in publishing an 18-page report on the effect of the drought on the State's agricultural sector (12).

Interagency Agricultural Information Task Force Role

The IAITF role was confined to education. The Task Force published 19 publications and distributed about 325,000 leaflets, brochures, and booklets to the California farming community. The four main channels through which the literature was distributed included the SCS, UC Extension Service, the State Drought Information Center, and county fairs.

1/ State of California Governor's Drought Emergency Task Force. Directory of State-Agency Drought Assistance Responsibilities. 1977.

Food and Agriculture Subcommittee

As discussed previously, the DFA was a member of the DTF. The DTF assigned to DFA three major lead agency responsibilities: 1) to estimate crop changes; 2) to evaluate the extent of possible crop acreage reduction; and 3) to analyze the economic effects of the drought on the California agricultural economy.

DFA response to this assignment was to form a special interagency subcommittee, entitled the Food and Agriculture Subcommittee (FAS). The FAS was chaired by the DFA. The DFA enlisted the assistance of an economist in the DWR's Planning Division, two economists from the Bank of America (B of A), an economist from the California Crop and Livestock Reporting Service (CCLRS), and several economists from the Economic Research Service (ERS).

The FAS began meeting in February 1977 and was active throughout 1977. The committee was de-activated in February 1978 following an announcement by State officials that the drought had been broken.

STUDY METHODOLOGY

The FAS used an increasingly sophisticated methodology as the drought progressed. This was a function of several factors: 1) an increase in availability of data; 2) the development of analytical capability; and 3) major decisions by State and Federal officials concerning surface water distribution policies.

The initial approach was to convene the FAS and obtain consensus judgment estimates for three alternative drought scenarios: pessimistic, optimistic, and most likely. In the next analytical phase, FAS used two existing linear programming (LP) models capable of separately analyzing the resource conditions of the San Joaquin and Tulare Basins within the San Joaquin Valley, the major area affected by the drought. During the second stage, the analysis was based on the differences between normal and drought conditions. The FAS still had very little solid data on the way in which surface and ground water would be available for irrigation purposes.

In the third analytical phase, the FAS continued to improve on the methodology which had been developed for the second phase. The analysis was still focused on the San Joaquin Valley, but the FAS made a conscious effort to extend the analysis to the State as a whole. By then, DWR and BuRec had made major decisions regarding surface water releases. For the first time, statistics on the extent of well drilling

in the Central Valley were released. The April 1, 1977 planting intentions for field crops report was seen as a much more reliable indicator of farmers' response to the drought than the January 1, 1977 report.

In the fourth analytical phase, the FAS shifted the emphasis to statewide analysis. For the first time, DWR employed an input-output model to evaluate the secondary impacts of the drought. The FAS provided an estimate of the drought effects for the top 20 farm commodities in the crop and livestock sector. The estimate of the State's gross and net farm income in comparison to previous years was based on the results of the two San Joaquin Valley LP models and judgment estimates for the remainder of the State.

DROUGHT ANALYSIS

Initial Analysis

The first round of analysis by the FAS was limited to roundtable discussions with FAS members attending the first meeting in February 1977. Three scenarios were developed focusing on the expected availability of irrigation water in the San Joaquin and Sacramento Valley Basins. These scenarios were entitled optimistic, most likely, and pessimistic by FAS. The FAS assumed that the San Joaquin Valley was the most adversely affected by the drought, with significant effects also experienced in the Sacramento Valley. The only effects in the remainder of the State were assumed to be those in the coastal valleys. The FAS made its projections under two different sets of responses to the drought. The first set of FAS projections was made under the assumption of a continuation of pre-drought practices. The second set was made under the assumption that the actions of farmers and water resource institutions would serve to reduce the economic losses by 20%. Anticipated actions included: 1) increasing production in California areas having adequate irrigation water supplies, e.g., the Imperial Valley; 2) shifting the proportion of water applied to highly valued crops; 3) adopting improved irrigation practices to increase irrigation efficiency; 4) idling marginal, low productivity lands; and 5) pumping ground water and overdrafting ground water basins.

The optimistic scenario assumed that the San Joaquin Valley would experience a 30% reduction in irrigation supplies. The Sacramento Valley reductions were assumed to be 15%. In this scenario and the other two, reductions for the rest of the State were assumed to be proportional to those of the San Joaquin Valley. Under this assumption, crop losses were about $282 million in the San Joaquin Valley, $34 million in cash grain crops in the Sacramento Valley, and only $15,000 in the rest of the State. Livestock losses were not disaggregated below the State level. Expected losses were $465 million, about 90% attributed to beef cattle.

The most likely scenario envisioned a severe drought similar to 1924 precipitation conditions. It was assumed that there would be a slight increase in available ground water. The water availability was assumed to be reduced by 35% in the San Joaquin Valley and by 20% in Sacramento Valley. This scenario projected an additional $400 million in crop losses in the San Joaquin Valley, $255 million of which was attributed to fruit and nut crops, and $50 million each for cotton and vegetables. Sacramento Valley losses were $84 million, with $50 million attributed to cash grains and $34 million to vegetables. Crop losses in the rest of the State were only $96,000. The livestock losses were $507 million, an increase of $50 million over the optimistic scenario.

The pessimistic scenario forecast a drought in which weather conditions were less favorable than in 1924 and

energy availability limited. The energy shortages were due to absolute limits on available energy and the possibility of rolling brownouts in the electrical energy delivery system. In this scenario, water availability would be reduced 40% in the San Joaquin Valley and 25% in the Sacramento Valley. The consequences of this extreme drought scenario were quite significant for crops in both the San Joaquin ($1.2 billion in losses) and the Sacramento Valleys ($130 million in losses). Losses were only $189,000 in the rest of the State. Compared to the most likely scenario, the major increases in crop losses were attributed by the FAS to fruit and nut crops (up $451 million) and cotton (up $58 million). The FAS projected that other crop losses would increase by $95 million. The increase in livestock losses was forecast at only $25 million.

In addition to in-state distribution, the initial FAS estimates were also sent to the USDA Drought Task Force in Washington, DC. The FAS emphasized that the loss estimates were preliminary. Compared to 1975, the last pre-drought year, the estimated gross value of direct losses was projected to range from $772 million under the optimistic scenario to $1.9 billion under the pessimistic scenario. The FAS alternative scenario under the five assumptions noted previously would have losses about 20% lower. The range for this lower set was from $605 million for the optimistic scenario to $1.5 billion for the pessimistic scenario.

The FAS also estimated the harvested irrigated acreage, indicating the extent to which the major crops would shift because of the drought conditions. The most likely harvested irrigated acreage would be about 4.2 million acres for the San Joaquin Valley (0.6 million acres below 1976) and about 1.3 million acres for the Sacramento Valley (0.4 million acres below 1976). The entire Central Valley acreage would be 16% lower than the 1976 harvested acreage.

March 1977 Analysis

The FAS made the second round of analyses in March, using the two San Joaquin Valley LP models for the first time. The area for these San Joaquin and Tulare Basin models is displayed in Figure 1. The two models had recently been used in the ongoing San Joaquin Valley River Basin Study. In the river basin analysis, the data reflected the conditions of 1972, the study's base year. In the drought analysis, the FAS updated the LP model coefficients to reflect 1977 conditions. The FAS also decided to use only two alternative scenarios -- without drought and with drought. Assumptions regarding each scenario are displayed in Tables 1-4.

The FAS made two sets of irrigation water supply estimates for the 1977 growing season (Table 1). The first set of estimates was made under the assumption of no drought conditions. The second set was made under the assumption of continued drought conditions.

Water supply in the San Joaquin Valley includes surface water and ground water. Under normal conditions for 1977, the San Joaquin Valley farmers would have expected about 7.8 million acre-feet (MAF) of surface water to be delivered to their farms. Surface water is the source for approximately 45% of the Valley's applied irrigation water during the growing season. The remainder of the applied irrigation water is pumped from the Valley's ground water supply.

The FAS based the availability of surface irrigation water for the San Joaquin Valley on recent public announcements from the DWR and BuRec. The DWR announced that surface water deliveries for the State Water Project (SWP) would be only 40% of normal for contract entitlement water and that there would be no deliveries of surplus water.1/ The BuRec announcement indicated that surface water deliveries to the Central Valley Project (CVP) would be only 25% of normal. Using past irrigation delivery patterns, the FAS estimated

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1/ Surplus water is a special water delivery category used by the DWR in conjunction with the State Water Project. It includes water supplies in DWR reservoirs which are deemed to be in excess of contractual agreements. It is made available to agricultural contractors depending on the extent to which DWR determines that prior years of above average precipitation can justify its distribution. A key ingredient in the DWR decision is the extent to which the long-term capability of meeting firm delivery contracts would be jeopardized.

SWP and CVP deliveries for the San Joaquin and Tulare Basins, the two subareas of the San Joaquin Valley.

The FAS estimated that the San Joaquin Valley could expect surface water deliveries to be only 22% of normal. There were two contributing factors which explain the drastic reduction in SWP and CVP deliveries to the Valley. The first was the fact that no SWP surplus water was to be delivered in 1977, which eliminated about 0.517 MAF in the Tulare Basin and 4,100 acre-feet in the San Joaquin Basin. The second was that Sacramento Valley agricultural contractors eligible to receive CVP water had higher priority water rights compared to the San Joaquin Valley contractors.

The FAS was aware of the growing concern about the availability of electricity in 1977. There were reports of possible brownouts, or even blackouts, during the summer. For this reason the FAS reduced its estimates of ground water availability for the San Joaquin Valley by 9% (Table 1).

The FAS was also concerned about the extent to which drought conditions would cause the San Joaquin Valley's cropping pattern to be changed. One possible source of information was the January 1, 1977 Planting Intentions Report for Field Crops. The report contained the California Crop and Livestock Reporting Service estimates of plantings for ten major field crops, including cotton, barley, winter wheat, durum wheat, alfalfa hay, corn, rice, sugar beets, sorghum, and oats. The estimates were based on a sample of farmers

Table 1

IRRIGATION WATER SUPPLIES
FAS Assumptions
March 1977

Area/Water Source	Condition			
San Joaquin Basin	No Drought	With Drought	Change	Percent Change
	1,000 Acre-Feet			
Surface Water	3.7a/	.8b/	-2.9	-78
Ground Water	2.5a/	2.0c/	0.5	-20
Basin Total	6.2	2.8	-3.4	-55
Tulare Basin				
Surface Water	4.1a/	.9b/	-3.2	-78
Ground Water	7.2a/	6.8c/	-0.4	- 6
Basin Total	11.3	7.7	-3.6	-32
San Joaquin Valley				
Surface Water	7.8	1.7	-6.1	-78
Ground Water	9.7	8.8	-0.9	- 9
Basin Total	17.5	10.5	-7.0	-40

a/ San Joaquin Valley River Basin Study figures for 1972.

b/ Based upon public announcements by the California Department of Water Resources and the U.S. Bureau of Reclamation

c/ Allowance was made for possible energy shortages which would limit ground water pumping.

within the State. The FAS felt that the January estimates were not reliable because the farmers had been surveyed in December 1976 before the drought had become an issue and well before the announced reductions in surface water deliveries.

Using the limited data available, the FAS developed some decision rules regarding expected cropping shifts for the San Joaquin Valley. These rules were employed in the analysis using the USDA's two LP models of the San Joaquin Valley.

Decision rules were established for the major crops and for the two basins (Table 2). The FAS recognized that the Tulare Basin depended less on surface water supplies for irrigation than the San Joaquin Basin. The harvested acreage of perennial crops, which included seven major fruit and nut crops, was not allowed to increase in either basin. The decision rule for the vegetable crops group, which included seven major vegetable crops, also specified no increase in acreage. The same rule was also used for cotton. Irrigated pasture acreage was expected to be at least as high as in 1976 because of rangeland shortage due to the drought. The limits placed on shifts for the other irrigated crops were tailored to the individual conditions of the Valley's two basins.

The FAS contacted several crop and irrigation specialists regarding the extent to which they could expect crop yields to change during the drought. The specialists said that if farmers were willing to take the risk, they could

Table 2

IRRIGATED ACREAGE SHIFT CONSTRAINTS
FAS Assumptions
March 1977

Area/Crop Group	Lower Limit	Upper Limit
	----As Percent of 1976----	
San Joaquin Basin		
Perennials	none	100
Vegetables	none	100
Cotton	none	100
Cash Grains	65	none
Other Field Crops	31	none
Pasture	100	none
Tulare Basin		
Perennials	60	100
Vegetables	89	89
Cotton	86	86
Cash Grains	61	61
Other Field Crops	20	20
Pasture	100	none

drastically reduce the usual amount of water which is applied to leach out salts from the crop root zone. Leaching is a necessary practice on the Valley's west side, but could be foregone for one season without yield reductions or excess salt buildup. The specialists also indicated that farmers would be able to increase their irrigation water use efficiency by using irrigation management scheduling, tailwater return systems, and other water-conserving practices. The irrigation specialists estimated the extent to which farmers in the two Valley basins could reduce their applied irrigation water application rates during the drought (Table 3). Rate reduction was projected to be generally higher for the San Joaquin Basin than for the Tulare Basin. This is a function of high evapotranspiration rates for the more southerly Tulare Basin, the extent to which salinity leaching was a problem, the water-holding capacity of the soils, and other factors. Rates for citrus, small grains, and corn for silage could be reduced more in the Tulare than in the San Joaquin Basin.

The crop specialists' consensus on projected crop yields is displayed in Table 4. The crop yield reductions would apply in the event that farmers attempted to conserve applied irrigation water to the extent that is displayed in Table 3. There were 24 crops for which projections were made. The crop specialists expected that the yields of only 14 of the 24 crops would be reduced. Twelve of these twenty-four crops

Table 3

APPLIED IRRIGATION WATER PER ACRE
Drought and No-Drought Conditions Comparison
San Joaquin Valley Basin
1977 Forecast

Crop	Area	
	San Joaquin Basin	Tulare Basin
	--Drought as Percent Normal Rate--	
Fruits and Nuts		
Almonds	74	94
Walnuts	100	100
Grapes	83	100
Deciduous a/	96	100
Citrus b/	75	69
Olives	77	91
Figs	100	100
Vegetables		
Lima beans	100	100
Lettuce	100	100
Melons, all	57	82
Potatoes	56	68
Tomatoes, processing	94	100
Field		
Small grains c/	77	72
Dry edible beans	80	80
Corn for grain	73	83
Corn for silage	87	80
Cotton	95	95
Alfalfa for hay	68	88
Alfalfa for seed	57	78
Safflower	77	89
Rice	100	100
Sorghum for grain	100	100
Sugar beets	67	95
Irrigated Pasture	100	100

Notes: a/ Peaches used as representative crop
b/ Oranges used as representative crop
c/ Includes barley and wheat

Source: Food and Agriculture Subcommittee forecast was based on conversations with University of California crop and irrigation specialists.

Table 4

IRRIGATED CROP YIELD PROJECTIONS
Drought Conditions
FAS Assumptions
March 1977

Crop	Drought Yield as Percent of Normal
	(1970-72 Average = 100)
Fruits and Nuts	
Almonds	95
Walnuts	100
Grapes	95
Deciduous	100
Citrus	100
Olives	95
Figs	100
Vegetables	
Lima Beans	95
Lettuce	100
Mellons, All	95
Potatoes	95
Tomatoes, Processing	95
Field	
Small Grains	92.5
Dry Edible Beans	95
Corn for Grain	90
Corn for Silage	95
Cotton	95
Alfalfa for Hay	100
Alfalfa for Seed	100
Safflower	95
Rice	100
Sorghum for Grain	100
Sugar Beets	95
Irrigated Pasture	100

Source: Food and Agriculture Subcommittee forecasts were based on conversations with University of California crop and irrigation specialists.

were projected to have yield reductions of 5%. Small grain crops were expected to have yield reductions of 7.5%, and yields of corn for grain would be reduced by 10%.

The FAS projected prices for the major crops in the San Joaquin Valley under normal and drought conditions (Table 5). The projected price increases under drought conditions for perennial crops were in the range of 2-15%. The FAS believed that farmers would make every possible effort to keep their perennial crops in production due to their high gross income values. Even without full water supplies, the farmers would seek to protect these trees and vines as a long term investment.

Price projections for vegetable crops were much more variable. The FAS estimated that the Valley's share of melons was about 40% of U.S. production, and they expected farmers there to shift to other crops. For this reason, the highly volatile melons price was expected to rise by 46%. In the case of lima beans, the Valley had a 30% share of U.S. production, but the FAS forecast only a 17% price rise. The lettuce price was increased by only 8% because the Valley's share of U.S. production was less than 5%. Even though the Valley usually produced about 30% of the Nation's processing tomatoes, the FAS projected no price effect. The FAS assumed that tomato processors would be able to contract for production in other areas of the State which either had firm surface water contracts or adequate ground water. Potato prices

Table 5

CROP PRICE PROJECTIONS FOR CALIFORNIA
With and Without Drought Conditions
Food and Drought Subcommittee
March 1977

Crop	Unit	March 1977 Without Drought	March 1977 With Drought
		dollars	
Fruit and Nuts			
Almonds	ton	690	750
Walnuts	ton	485	550
Grapes	ton	145	166
Deciduous[a]	ton	124	133
Citrus[b]	ton	165	173
Olives	ton	340	350
Figs (dried)	ton	810	825
Vegetables			
Beans, Lima	ton	320	375
Melons[c]	ton	205	300
Potatoes	ton	80	80
Tomatoes, Proc.	ton	55	55
Lettuce	ton	111	120
Field Crops			
Barley/Wheat	ton	100	100
Dry Edible Beans	ton	410	600
Corn for Grain	ton	105	105
Cotton, 480#	bale	317	335
Alfalfa Hay	ton	72	90
Rice	ton	132	135
Safflower	ton	225	250
Alfalfa Seed	lb.	74	1.00
Sorghum for Grain	ton	100	100
Sugar Beets	ton	21	21

Notes: a/ Peaches were used as the representative crop.

b/ Oranges were used as the representative crop.

c/ Cantaloupes were used as the representative crop.

were assumed to be unaffected because of the Valley's small (5%) share of the national market.

The FAS price forecasts for field crops were even more variable than for perennials or vegetable crops. The largest field crop price increase, up 46%, was projected for dry edible beans, a crop for which the San Joaquin Valley had about 10% of U.S. production. The second highest projected increase was for alfalfa seed, of which 2/3 of the Nation's production is grown in the Valley. The price of alfalfa hay was projected to increase 25%, largely because the FAS felt that the drought was forcing range cattle to be fed hay. Except for safflower, the prices for three other field crops were projected to rise by no more than 6%. The drought was expected to have no effect on prices of four crops -- barley, winter wheat, sorghum for grain, and sugar beets.

Using the two San Joaquin Valley models, the FAS analyzed the anticipated effects of the 1977 drought. The resource constraints, crop prices, and yields described in Tables 1-5 were incorporated into these models. Further detail on these two models is provided in Appendix B.

A total of 11 alternative drought and no drought scenarios were evaluated (Table 6). The FAS specified a 1977 No Drought scenario for comparative purposes. The Reference Base scenario represented the Subcommittee's most likely 1977 drought scenario, based on the latest available information. The Reference Base assumptions of irrigation water availabil-

Table 6

NET RETURN COMPARISONS
Drought and No Drought Conditions
FAS Alternative Scenarios
San Joaquin Valley Basin
March 1977

Resource Conditions	Price Set	Total Irrigation Water	Net Returns $ Million	Net Returns As % of No Drought Conditions
		---MAF----		
No Drought	no drought	17.5	1,212	100
With Drought Reference Base (RB)	no drought	10.5	903	74
Reference Base	with drought	10.5	1,176	97
RB + 5% GW a/	with drought	11.0	1,297	107
RB + 10% GW b/	with drought	11.4	1,333	110
RB + 15% GW	with drought	11.8	1,369	113
RB + 20% GW	with drought	12.3	1,385	114
RB - 5% GW	with drought	10.1	1,163	96
RB - 10% GW	with drought	9.6	1,151	95
RB - 15% GW	with drought	9.2	1,139	94
RB - 20% GW	with drought	8.8	1,115	92

a/ Reference Base plus 5% additional ground water supply beyond the FAS expectation for ground water availability during the 1977 irrigation season.

b/ In this and the other resource condition scenarios, ground water was varied in 5% increments to ground water levels that were a maximum of 20% above and 20% below the Reference Base assumption.

ity were presented under the "With Drought" column in Table 1. The other drought scenarios are variations of the Reference Base with respect to crop price or ground water availability.

The Reference Base resource conditions were evaluated under the two alternative crop price sets presented in Table 5. When the No Drought price set was used in conjunction with Reference Base resource conditions, net returns were only 74% of those forecast under the No Drought condition. When the Reference Base conditions were evaluated with the With Drought price set, the two LP models forecast that the Valley's net returns would be 97% of those forecast under the No Drought scenario.

The FAS evaluated eight other With Drought scenarios. The only variation between these scenarios was the extent to which ground water was assumed to be available to the Valley's farmers. The FAS increased and decreased ground water availability in 5% increments from its Reference Base ground water availability levels. The maximum ground water supply level was 20% above the Reference Base and the minimum supply was 20% below it. Even with ground water at the highest level, the Valley's total irrigation water supply was still assumed to be 30% below the No Drought condition.

The net returns associated with the alternative water availability scenarios were highly variable. As ground water availability was increased above the Reference Base levels,

the LP models predicted that net returns would rise from 97-114% of the No Drought estimate. As ground water availability was decreased net returns fell, but more slowly. With ground water availability 20% below the Reference Base levels, net returns were 92% of No Drought levels, a decrease of only 8%.

The reason for the net return differences can be attributed to the differences in crop mix as water supplies are varied. A comparison of the Valley's crop acreage under No Drought, Reference Base, maximum ground water, and minimum ground water conditions is displayed in Table 7. Under No Drought conditions, the FAS projection was for over 5 million acres of irrigated land. Under the Reference Base drought conditions, only 3.8 million acres would be irrigated, a decrease of 1.2 million acres, or 25%. The three most highly profitable crops were fruit and nuts, vegetables, and cotton. Under Reference Base conditions, these three crops would decline 148,000 acres, or only 12% of the decreased acreage of all crops. The largest decline of acreages were in alfalfa hay (down 313,000 acres) and barley and wheat (down 292,000 acres). These crops were far less profitable on a per acre basis than the fruit and nut, vegetable, and cotton crops.

The acreage changes projected to occur with a 20% ground water increase above the Reference Base illustrate why net returns change more dramatically with increasing than de-

Table 7

IRRIGATED CROP AND PASTURELAND
Drought and No Drought Conditions
4 FAS Alternative Scenarios
San Joaquin Valley Basin
March 1977

Crop Group/Crop	No Drought	Alternative Drought Scenario: Reference Base	RB +20% GW[a/]	RB -20% GW[b/]
	----------1,000 Acres----------			
Fruit and Nut	1,162	1,052	1,162	1,052
Vegetables	228	204	218	204
Cotton	923	909	909	909
Cash Grains				
Barley and Wheat	823	531	719	40
Corn	144	97	97	-0-
Sorghum	107	69	80	2
Rice	40	25	25	-0-
Subtotal	1,114	722	921	42
Other Field Crops				
Alfalfa Hay	586	273	434	273
Silage	137	84	97	10
Sugar Beets	117	33	33	33
Seed, Alfalfa	97	29	88	29
Dry Edible Beans	75	26	35	26
Safflower	59	18	56	18
Other Field	88	22	22	22
Subtotal	1,159	485	765	411
Irrigated Pasture	445	445	445	445
GRAND TOTAL	5,031	3,817	4,420	3,063

a/ Reference Base plus 20% additional ground water supply beyond the FAS expectation for ground water availability during the 1977 irrigation season.

b/ Reference Base minus 20% additional ground water supply below the FAS expectation for ground water availability during the 1977 irrigation season.

creasing ground water supplies. In the case of increasing ground water, the fruit and nut acreage increased by 110,000 acres, accounting for 18% of the 603,000 additional acres. The remaining 477,000 acres that would be brought back into production were in the cash grains (up 199,000 acres) and other field crops (up 280,000 acres) categories.

In the declining ground water scenario, there was no decrease in the acreage of the three most profitable crops compared to the Reference Base. By contrast, the less profitable crops declined by over 3/4 million acres. The acreage decrease was 25% greater under the declining ground water scenario than the increasing ground water scenario. The difference was that the less profitable crops also used less water -- hence the more modest net return effects.

April 1977 Analysis

In early April 1977, the DWR director queried irrigation districts with respect to their preference concerning 1977 water deliveries. They were given two options as follows: 1) to accept limited SWP deliveries in both 1977 and 1978; or 2) to accept a maximum delivery in 1977 followed by a 1978 delivery contingent upon the runoff patterns for the 1978 water year. There was a distinct possibility that very little water would be available for the 1978 irrigation season if the maximum possible delivery was accepted for 1977.

The irrigation district responses were overwhelmingly in

favor of maximum possible SWP deliveries in 1977. The DWR proceeded to transfer water from the Oroville Reservoir in northern California to the San Luis Reservoir, the key storage facility in the San Joaquin Valley.

The decision had three potential effects on agriculture:

1. The SWP could have very little irrigation water in 1978 and in subsequent years, unless exceptionally heavy precipitation was received.

2. Lake Oroville, behind Oroville Dam, would be completely dry by April 1978 unless normal rainfall was received during the 1978 water year.

3. Oroville Dam's reduced releases in 1978 and subsequent years could cause salt-water intrusions that could render the Sacramento-San Joaquin Delta's water completely unusable, requiring as long as two years of favorable water supplies to flush it out.

The effect of the new DWR policy on the Valley's irrigation season was an increase in surface water deliveries from about 1.75-4.8 MAF. Although this is still below the 7.8 MAF of normal surface deliveries, it was a dramatic improvement for the Valley's farming community.

Later in April 1977, the DWR made public announcements regarding changes in its estimates of ground water availability for the San Joaquin Valley. The FAS estimate of the combined effects of the latest surface and ground water availability is presented in Table 8.

When compared to Table 1, the latest irrigation water changes were very striking. Instead of a 40% decline in the Valley's total irrigation water availability, the decline was

Table 8

IRRIGATION WATER SUPPLIES
FAS Assumptions
Most Likely Drought Scenario
April 1977

Area/Water Source	Condition			
San Joaquin Basin	No Drought[a]	With Drought[b]	Change	Percent Change
	1,000 Acre-Feet			
Surface Water	3.7	2.8	-0.9	-24
Ground Water	2.5	2.5	-0-	-0-
Basin Total	6.2	5.3	-0.9	-15
Tulare Basin				
Surface Water	4.1	2.2	-1.9	-46
Ground Water	7.2	7.2	-0-	-0-
Basin Total	11.3	9.4	-1.9	-17
San Joaquin Valley				
Surface Water	7.8	5.0	-2.8	-36
Ground Water	9.7	9.7	-0-	-0-
Basin Total	17.5	14.7	-2.8	-16

a/ San Joaquin Valley River Basin Study figures for 1972.

b/ DWR announcements made in April 1977 and U.S. Bureau of Reclamation announcements made in February 1977.

estimated to be only 16%. Compared to the March estimate (Table 1), the April estimate showed Valley surface water supplies up 3.3 MAF, or 194% higher. The ground water increases were also significant -- up 0.9 MAF. This represented an increase of 10% over the FAS ground water estimates used in the March Reference Base analysis.

The FAS met to revise its assessment of the drought and decided to return to the three-scenario approach used earlier in the year, and to incorporate both the latest water availability data and the farmers' planting intentions report. The California farmers' planting intentions report indicated a combined acreage decrease of 5% for eight major field crops during the three-month period from January 1 April 1, 1977 (Table 9).

The three FAS scenarios varied the San Joaquin Valley water availability estimates slightly above and below the latest DWR estimates. The Most Likely scenario estimated ground water pumping to continue at the 1972 rate, the most recent pre-drought year for which a complete set of estimates was available. Surface water availability was estimated on the basis of the April 1977 DWR announcement. The FAS Optimistic scenario assumed that an additional 0.9 MAF of surface water would be made available to the Tulare Basin. Other than this, the Optimistic scenario was identical in other respects with the Most Likely scenario. The Pessimistic scenario included several differences from the Most Likely

Table 9

SELECTED CALIFORNIA FIELD CROP
PLANTING INTENTIONS AND PLANTED ACREAGE
1976 and 1977

Crop	1976 Plantings	Planting Intentions: Jan. 1, 1977	Planting Intentions: April 1, 1977	Change: 1976 to April 1, 1977	Change: Jan. 1977 to April 1977
	1,000 Acres			Percent	
Cotton	1,130	1,400	1,350	+19	- 4
Alfalfa Hay	1,630	1,670	1,670	+ 2	-0-
Barley	1,200	1,200	1,150	+ 4	- 4
Wheat, Winter	1,000	885	885	-11	-0-
Corn, All	480	490	430	-10	-12
Rice	421	400	345	-18	-14
Sugar Beets	318	270	235	-26	-13
Sorghum, All	235	215	150	-36	-30
TOTAL	6,414	6,530	6,215	- 3	- 5

Source: California Crop and Livestock Reporting Service

scenario. The first difference was that 0.1 MAF less surface water was assumed to be available in the San Joaquin Basin. The second difference was that the FAS used the same ground water availability as it had used in the March 1977 Reference Base scenario (Table 1). In the specification of all three scenarios, the FAS assumed that farmers would use their most efficient irrigation water use strategy as indicated in Table 3.

Based on the latest farmers' planting intention reports, the FAS revised the crop shift rules for the two San Joaquin LP models (Table 10). The FAS was faced with the dilemma that both of the 1977 planting intentions reports were not disaggregated to sub-state levels. The California Crop and Livestock Reporting Service (CCLRS) had developed its farmer sampling design on the basis of providing statewide estimates. The CCLRS maintained that its statistical procedures could not be adapted to forecast individual San Joaquin Valley crop acreages.

The FAS had to make its own judgment estimate regarding the extent of regional differences in crop acreage changes within the State. A further problem faced by the FAS was that the CCLRS did not distinguish between irrigated and dryland acreage in the planting intentions estimates. The two major Valley crops which were grown under both irrigated and dryland conditions were barley and winter wheat.

The three scenarios were analyzed using the San Joaquin

Table 10

IRRIGATED ACREAGE SHIFT ASSUMPTIONS
Three FAS Scenarios
April 1977

Crop Group/Crop	Water Scenario: Optimistic	Most Likely	Pessimistic
	---------Upper Limit as Percent of 1976---------		
Perennials	100	90	80
Tomatoes, All	85	85	85
Cotton	100	100	100
Cash Grains			
Barley and Wheat	100	100	100
Rice	40	40	40
Field Crops			
Alfalfa Hay	100	90	80
Sugar Beets	65	65	65
Double Crops[a/]	100	-0-	-0-
Other Crops	100	100	b/
Irrigated Pasture	100	90	80

a/ Includes barley or wheat followed by silage, barley or wheat followed by sorghum grain, and two crops of vegetables.

b/ Reference Base assumptions for March 1977 -- see Table 2.

Valley LP models. The most surprising forecast was that irrigated crop farm net returns could be nearly as high with the drought (Table 11). This result was under the Most Likely scenario using the with drought crop price set. The net return from this combination was only 2% lower than the No Drought scenario estimate. It should be noted that this estimate applies only to irrigated farms in the San Joaquin Valley and does not measure the net returns to the Valley's dryland crop or livestock farms or to farms in other areas of California. When the no drought price set was used in the Most Likely scenario, the Valley's irrigated crop farmers were expected to experience drought-related losses of about 14%.

Total irrigated acreage under the Most Likely scenario would be about 4.66 million acres (Table 12). This represents a 373,000-acre, or 7% decline, compared to the FAS No Drought acreage. The two leading declining crops were fruit and nut (down 116,000 acres) and field crops (down 117,000 acres). All other irrigated crops accounted for the remaining reduction of 139,000 acres.

The Optimistic scenario was evaluated only with the no drought crop price set. The LP model solutions indicated that the net returns San Joaquin Valley farmers could expect would be about 8% lower than the No Drought scenario predicted. The biggest surprise to the FAS was that irrigated crop acreage was projected to decline by only 2% compared to

Table 11

NET RETURN COMPARISONS
Drought and No Drought Conditions
FAS Alternative Scenarios
San Joaquin Valley Basin
April 1977

Resource Conditions	Price Set	Total Irrigation Water	Net Returns $ Million	Net Returns As % of No Drought Conditions
		---MAF----		
No Drought	no drought	17.5	1,212	100
With Drought				
Optimistic	no drought	16.3	1,121	92
Most Likely	with drought	14.7	1,195	98
	no drought	14.7	1,037	86
Pessimistic	with drought	13.7	1,124	93
	no drought	13.7	937	77

Source: 1. Tables 5, 8, and 9

2. Computer solutions from San Joaquin and Tulare Basin LP models.

Table 12

IRRIGATED CROP AND PASTURELAND
Drought and No Drought Conditions
FAS Alternative Scenarios
San Joaquin Valley Basin
April 1977

Crop Group/Crop	No Drought	Alternative Drought Scenario: Optimistic	Most Likely	Pessimistic
	1,000 Acres			
Fruit and Nut	1,162	1,162	1,046	930
Vegetables	228	209	209	209
Cotton	923	923	923	923
Cash Grains				
Barley and Wheat	823	823	788	788
Corn	144	144	144	144
Sorghum	107	107	90	90
Rice	40	16	16	16
Subtotal	1,114	1,090	1,038	1,039
Field Crops				
Alfalfa Hay	586	586	527	469
Silage	137	136	119	101
Sugar Beets	117	76	76	76
Seed, Alfalfa	97	97	97	97
Dry Edible Beans	75	75	75	75
Safflower	59	59	59	59
Other Crops	88	88	88	88
Subtotal	1,159	1,118	1,042	966
Irrigated Pasture	445	445	400	356
GRAND TOTAL	5,031	4,947	4,658	4,422

Source: 1. Tables 8 and 9.

2. Computer solutions from San Joaquin and Tulare Basin LP models.

the No Drought scenario. This can largely be attributed to the FAS assumption that farmers would improve their irrigation water use efficiency during the drought (Table 3).

The Pessimistic scenario was assessed even though the FAS generally felt that it was not very likely to occur because of resource adjustments that were being made by individual farmers and by the agencies that served the Valley's agricultural community. This scenario forecast a 7% decline in net returns under the with drought price set and a 23% decline under the no drought price set. Irrigated acreage was forecast to decline by 609,000 acres, or about 12%. The declines in fruit and nut crops were projected to be major, accounting for a reduction of 232,000 acres, or 38% compared to the No Drought scenario. The second major declining crop was alfalfa hay, down 117,000 acres, or 19%. The third major declining crop was irrigated pasture, forecast to be down 89,000 acres, or 15%. All other crops accounted for a decline of 171,000 acres, or 28% of the total forecast decline.

May 1977

In May 1977, the FAS elected, for the first time, to use a best judgment, single scenario approach in making its evaluation of the drought's effects. Information available to the FAS indicated that ground water supplies for agriculture were being increased at record rates. The DWR reported that

many new wells had already been dug, and farmers were planning to dig even more during the summer. Drilling firms were coming from out-of-state to offer their services to farmers. A number of interagency agreements had been made to redistribute surface water. One of these agreements concerned SWP water, which was turned back to Valley farmers by the Metropolitan Water District (MWD) in southern California.

The FAS assumed that the surface water available for irrigation in the San Joaquin Valley in May would be the same as in April, but available ground water was 25% higher. Because of the improvement in irrigation water supply, the FAS felt that farmers would be likely to conserve water by raising crops with lower water requirements, but would be less likely to increase water use efficiency to the extent envisioned earlier in the spring (Table 3). By the same token, the FAS decided that irrigated crop yields would be those of a normal year. The FAS also felt that it would no longer be appropriate to use its with drought price set.

The FAS incorporated its May 1977 single scenario assumptions into the two San Joaquin Valley LP models. The results of the analysis are displayed in Tables 13 and 14. The amount of water available was assumed to be 17 MAF, about 3% less than in 1972. The biggest difference was that, in the no drought year, about 45% of the irrigation water was supplied from surface water sources. In its May 1977 scenario, the FAS assumed that surface water sources would account

Table 13

DROUGHT AND NO DROUGHT COMPARISONS
FAS Alternative Scenarios
San Joaquin Valley Basin
May 1977

Irrigation Water by Source	Unit	No Drought[a]	March 1977[b]	April 1977[c]	May 1977[d]
			Date of Drought Estimate		
Surface	1,000 Acre-Feet	7.8	1.7	5.0	4.8
Ground	1,000 Acre-Feet	9.7	8.8	9.7	12.2
TOTAL	1,000 Acre-Feet	17.5	10.5	14.7	17.0
Net Returns	Million $	1,212[e]	1,176[f]	1,195[f]	1,277[e]

a/ Based on 1972 data. Inefficient irrigation water use.

b/ FAS Reference Base scenario. Efficient irrigation water use.

c/ FAS Most Likely scenario. Efficient irrigation water use.

d/ FAS Single scenario. Inefficient irrigation water use.

e/ No drought price set, full yields.

f/ With drought price set, drought yields.

Source: Tables 1-12

Table 14

IRRIGATED CROP AND PASTURELAND
Drought and No Drought Conditions
FAS Alternative Scenarios
San Joaquin Valley Basin
May 1977

Crop Group/Crop	No Drought[a/]	March 1977[b/]	April 1977[c/]	May 1977[d/]
	Date of Drought Estimate			
	---1,000 Acres---			
Fruit and Nut	1,162	1,052	1,046	1,157
Vegetables	228	204	209	203
Cotton	923	909	923	1,275
Cash Grains				
Barley and Wheat	823	531	788	887
Corn	144	97	144	136
Sorghum	107	69	90	44
Rice	40	25	16	4
Subtotal	1,114	722	1,038	1,071
Field Crops				
Alfalfa Hay	586	273	527	631
Silage	137	84	119	102
Sugar Beets	117	33	76	77
Seed, Alfalfa	97	29	97	97
Dry Edible Beans	75	26	75	83
Safflower	59	18	59	59
Other Crops	88	22	88	88
Subtotal	1,159	485	1,042	1,137
Irrigated Pasture	445	445	400	445
GRAND TOTAL	5,031	3,817	4,658	5,288

a/ Based on 1972 data.

b/ FAS Reference Base scenario.

c/ FAS Most Likely scenario.

d/ FAS Single scenario.

Source: Tables 1-13

for only 28% of the total. The difference would be made up by ground water.

In the May analysis net returns to irrigated crop farmers in the San Joaquin Valley would be about 5% higher than under the No Drought Scenario, despite the use of the no drought price set, inefficient irrigation water use coefficients, and a somewhat lower total water supply. This finding was optimistic because lack of data prevented explicit consideration of certain factors in the LP analysis. These factors included the extra costs associated with pumping ground water from greater depths due to falling water tables, the high costs of drilling and operating new wells, higher surface water charges for SWP users, and the costs of conveying water from one irrigation district to another. For example, the per acre-foot SWP costs to member districts were later estimated to have risen from $15.00 in 1976 to $44.27 in 1977 (20). This increase alone would have cost $10 million, not including any other related irrigation district costs which would have been passed on to farmers.

An interesting finding was that the Valley's irrigated acreage was projected to rise 5% compared to the No Drought scenario. This forecast occurred despite a 3% decline in irrigation water. The forecast changes in crop mix indicated that high irrigation water requirement crops had declined, e.g., rice, whereas low water use crops were increased, e.g., barley and wheat.

The FAS was aware of many uncertainties regarding the data and assumptions on which its analysis was based. The May analysis was the last separate analysis of the San Joaquin Valley. Subsequent analysis focused on Statewide effects.

Summer 1977

The FAS prepared and distributed a drought report in August 1977 (12). The report indicated that the State's agricultural losses would range from $500 million to $1.5 billion, with $800 million the most likely figure. Gross farm income for 1977 was projected to decline by only $89 million, or about 1%, but net farm income would decline by $446 million, or 17%. The distribution of drought effects was found to be uneven -- some farmers were better off because of higher prices, whereas other farmers without sufficient water supplies were badly hurt. The report concluded that:

> Much of the loss identified as potential in early 1977 was averted by the prompt response of agriculturalists to the warnings of the impending drought and to their increased plantings of higher income producing crops in the desert and other areas of the State, where water was more available.

The report stated that if there were to be a third year of drought, and if it were to affect not only the Central Valley but also southern California and the coastal regions as well, "the impact on agriculture will be truly pronounced."

The DWR estimated the employment effects of the drought. It estimated that 1,449 persons were laid off because of the drought for the period from January 1 - September 16, 1977.1/ The DWR reported that the actual impact of the drought was less than had been expected by the State Department of Employment Development earlier.

1978 Forecast -- Had the Drought Continued

As the FAS looked ahead to 1978 under continued drought conditions, the outlook was very bleak. The only bright spot was the capability of irrigated farms to expand ground water supplies. During the drought, a record number of new wells was drilled (Table 15). DWR reported 15,960 wells drilled during the 1977 water year, compared to only 8,520 during the 1975 water year, an increase of 87%. During the period July 1 - September 30, 1977, the drilling of 6,600 wells was reported, an increase of 76% from the preceding quarter. About 40% of these new wells were drilled in the San Joaquin Valley and 18% in the Sacramento Valley. The major disadvantages of the continued record rates of well drilling were threefold -- high costs, worsening of the overdraft problem, and ground subsidence. Another problem was that new ground water sup-

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1/ Dept. of Water Resources. Drought Information Bulletin No. 32. Oct. 3, 1977. Pg. 2.

Table 15

NUMBER OF WELL DRILLERS REPORTS
Received by DWR
1974-1977

Period	1974-1975	1976-1977
October - December	1,970	2,090
January - March	1,890	3,520
April - June	2,050	3,750
July - September	2,610	6,600
TOTAL	8,520	15,960
Monthly Average	710	1,330

Source: California Water Supply Outlook, Sept. 5, 1978 report

plies were only available in selected areas of the State. In order to expand ground water supplies, underground aquifers had to have enough high quality ground water that could be lifted economically to irrigate the crops grown in the particular area.

The surface water situation was quite grim. The DWR made estimates of water availability under a recurrence of 1977 conditions (Table 16). The reservoir inflows for seven major reservoirs serving the Central Valley indicated that 1978 conditions would be only 24% of normal. Even if all of the available water were to be released from these seven reservoirs, the amount supplied would only be 50% of normal. This would not allow for any residual storage in the 1979 water year.

Unless there was an unexpected reversal in the water resource conditions, a drought extending into 1978 would result in the following consequences:

1. Water supplies from the CVP and SWP would be severely curtailed.

2. Continued heavy pumping of ground water in the Central Valley could potentially cause well collapse, ground subsidence, and associated adverse effects.

3. Areas which are dependent on surface irrigation water would significantly reduce row and field crop acreage and could lose significant orchard and vine acreages as well.

4. The livestock industry would be severely crippled, and its recovery would take several years, even under ideal climatic and economic conditions.

Table 16

PROJECTED 1978 WATER SUPPLY
Repetition of 1977 Water Year Runoff in 1978
Selected Reservoirs
Normal and 1978 Projected

Agency/Reservoir	Reservoir Inflows			Reservoir Release	
	Normal Year[a]	1978[b]	% of Normal	1978[c]	% of Normal
	--------MAF------		--MAF--		
BuRec					
Clair Engle Lake	1,243	196	16	361	37
Shasta	5,710	2,170	38	2,622	93
Millerton Lake	1,659	280	17	388	23
Subtotal	8,612	2,646	31	3,371	61
DWR					
Oroville	4,350	750	17	1,194	65
Other					
Don Pedro	1,367	173	13	338	33
Lake McClure	920	115	13	223	23
Pine Flat	1,568	305	19	368	23
Subtotal	3,855	593	15	929	26
GRAND TOTAL	16,817	3,989	24	5,494	50

a/ Long-term mean annual inflow.

b/ 1978 inflow equals that for 1977, and adjusted for evaporation by approximate methods.

c/ With no residual storage for carry-over into the 1979 water year, and all reservoirs drawn down to minimum (dead) storage by Sept. 30, 1978.

Source: State of California, The Resources Agency, Dept. of Water Resources, The Continuing California Drought, August 1977, pg. 121.

5. Many small farmers would require extensive assistance from public agencies to remain viable farm operations.

The 1978 water supply situation for the San Joaquin Valley would be less favorable than in the Reference Base scenario which the FAS developed as the most likely scenario in March 1977. Surface water rights for the Sacramento Valley were much stronger than those for the San Joaquin Valley. This would, of course, result in less surface water delivery to the San Joaquin Valley than under the March 1977 Reference Base. Even with a continued major expansion in well drilling, there would be a significant shortfall in water availability compared to 1977.

<u>1978 Actual -- The Drought is Broken</u>

Beginning in January 1978, the State's water supply situation began to improve dramatically. By late July, the State's ten major water reservoirs were at 93% of total capacity (Table 17). Although farmers continued to drill new wells in 1978, the rate began to taper off beginning in June as drought fears eased.

In order to monitor the drought in 1978, the ERS staff developed a new linear programming model which could evaluate both the San Joaquin and Sacramento Valleys. The new model was conceptually similar to the two San Joaquin Valley models which formed the core of the FAS drought analysis in 1977. The new LP model contained the four major regions in the

Table 17

RESERVOIR STORAGE COMPARISONS
Ten Major California Reservoirs
1976, 1977, and 1978

Agency/Reservoir	Capacity	Storage by Date: Nov. 1, 1976	Nov. 1, 1977	July 25, 1978
	Million Acre-Feet			
BuRec				
Clair Engle Lake	2.45	1.32	.22	1.98
Shasta	4.55	1.49	.65	4.48
Millerton Lake	.52	.23	.18	.47
Subtotal	7.52	3.04	1.05	6.93
DWR				
Oroville	3.54	1.74	.90	3.41
Joint BuRec-DWR				
San Luis	2.04	.81	.20	2.02
Other				
Don Pedro[a/]	2.03	.67	.30	1.67
Lake McClure[b/]	1.03	.24	.09	.98
Pine Flat[c/]	1.00	.23	.08	.93
Hetch Hetchy[d/]	.36	.20	.09	.36
Subtotal	4.42	1.34	.56	3.94
GRAND TOTAL	17.52	6.93	2.71	16.30
Percent of Capacity	--	40	15	93

a/ Operated by the Turlock-Modesto Irrigation District.

b/ Operated by the Merced Irrigation District.

c/ Operated by the U.S. Corps of Engineers.

d/ Operated by the City and County of San Francisco.

Source: Calif. Dept. of Water Resources, California Water Supply Outlook Reports for November 1, 1977 and July 25, 1978.

Central Valley, including the Sacramento, the Delta Central, the San Joaquin, and the Tulare regions. The four regions represented whole-county approximations to the four hydrologic subareas (HSA) used by DWR to define the Central Valley.

The new four-region model was used to evaluate the Central Valley's agriculture in 1978. The first application of the model was an evaluation of the effects of the January 1, 1978 CCLRS planting intentions report. The February 1978 ERS report indicated that net revenue for the Valley's irrigated crop sector would rise by about 3% when compared to 1976 (27).

The second use of the new four-region model was in an evaluation of the effects of two subsequent CCLRS planting intentions reports, the March 1978 report for processing tomatoes and the April 1, 1978 report for major field crops. The LP model results indicated a 2% increase in the Valley's net income compared to the February 1978 ERS report (28).

The third and final application of the four-region model was to assess the implications of four CCLRS reports which were released between June 30 and July 12, 1978. The model's evaluation of these reports indicated several key findings (29). First, fruit and nut production in the Central Valley was lower than normal because of a late, wet spring. Second, the Central Valley's planted acreage of major field crops was 1% higher than estimated in the February 1978 report. Third,

applied irrigation water would be about 8% higher than forecast in the February report. Fourth, the Central Valley's estimated net revenues for the modeled irrigated crops would be about 14% lower than forecast in the February report. This was primarily due to lower yields for several key fruit and nut crops.

THE DROUGHT IN RETROSPECT

Although the drought affected the economy of the Central Valley, it was far less serious than initially anticipated. The DWR analysis found some evidence that the drought may have caused an impact on the overall economy. The DWR reported (23) that:

> In comparing regional indices of business activity for 1977, the Sacramento Valley, San Joaquin Valley, and the Northern Coastal Area, which includes the San Francisco Bay, have flat periods with low growth. These areas experienced the bulk of the drought impacts. In contrast, the Southern California Area, which had few drought problems showed a business activity index of growth in 1977 without interruption. During this period, the United States economy was generally expanding and there are few reasons to explain the slowdowns in Northern and Central California, other than the drought.

Water Use

Water use during the four water years from 1975-78 was affected by the drought. Total water use during this period was less affected than the water source. The total water use ranged from a low of 26.5 MAF in 1978 to a high of 28.6 in 1976 (Table 18). During the depths of the drought in 1977, water use was only 5% less than in 1976, the peak year of this four-year interval. The 1977 water year was 1% higher than 1975 and 2% higher than 1978.

The shifts in water source graphically display the extent to which the drought affected the Central Valley. In the two non-drought years of 1975 and 1978, surface water sources accounted for about 60% of the Valley's total water

Table 18

ESTIMATED WATER USE BY SOURCE
Central Valley Region
1975-1978 Water Years

Year/ DWR Region	Sacramento	San Joaquin	Tulare Lake	Total
	DWR Region			
	Million Acre-Feet			
1975				
Surface	4.97	4.02	6.26	15.25
Ground Water				
-Local	1.37	2.52	6.42	10.31
-Overdraft	--	.31	1.03	1.34
Total	6.34	6.85	13.71	26.90
1976				
Surface	4.79	3.70	4.30	12.79
Ground Water				
-Local	1.46	2.82	7.89	12.17
-Overdraft	--	.71	2.96	3.67
Total	6.25	7.23	15.15	28.63
1977				
Surface	4.50	2.31	2.16	8.97
Ground Water				
-Local	1.58	3.31	7.83	12.72
-Overdraft	.60	1.18	3.79	5.57
Total	6.68	6.80	13.78	27.26
1978				
Surface	4.97	3.90	6.90	15.77
Ground Water				
-Local	1.54	1.50	4.10	7.14
-Overdraft	--	1.10	2.50	3.60
Total	6.51	6.50	13.50	26.51

a/ Excludes about 1 million acre-feet because certain information was unavailable.

Source: 1. California Dept. of Water Resources, The 1976-1977 California Drought: A Review, Table 3, pg. 15, May 1978.

2. Author's personal conversation on May 5, 1981 with Jerry D. Vayder provided the basis for extent of excluded water use for the Sacramento Region.

use. In 1976, the first drought year, the proportion of surface water use fell 15 percentage points to 45%. By 1977, the share of water use supplied by surface sources fell an additional 12 percentage points to 33%. After the drought broke in 1978, the share of water use supplied by surface sources increased to 60%, approximately the same as in 1975, the last pre-drought year. Ground water use increased during the 1975-77 period, but declined substantially in 1978 as less costly surface water supplies were once again available.

Ground water as a source is divided into two categories by the DWR -- local ground water and ground water overdraft. Local ground water includes pumping at rates which can be sustained either through natural replenishment or recharging of the ground water supplies from imported water. Overdraft is the mining of ground water, that is, the removal of water that cannot be replaced through natural means or artifical recharge.

The drought history of the Central Valley can be readily traced by assessing the extent to which ground water overdraft occurred during 1976 and 1977. In 1976, the overdraft was 3.67 MAF, which was over 2 1/2 times the amount in 1975. The 1977 overdraft was over 50% higher than in 1976 -- 5.57 MAF. By 1978, the overdraft had declined to 3.60 MAF, approximately the same level as in 1976. Within the Central Valley, the major share of the overdraft occurred in the Tulare Lake Region. The Tulare overdraft for the years

1975-78 accounted for 77%, 81%, 68%, and 69% of the Valley's overdraft. The San Joaquin Region was very consistent in the share of the Valley's overdraft ranging from 19-23% of the total. The Sacramento Region only experienced one year of overdraft -- in 1977, during the peak of the drought, there was 0.60 MAF of overdraft.

Agricultural Impacts

The indices of crop acreage for pre-drought, drought, and post-drought conditions are presented in Table 19. Total crop and pasture acreage for major crops was higher in 1976, declined slightly in 1977, and fully recovered in 1978. In 1976, total acreage was 3% above the average of the three pre-drought years 1973-75. In 1977, the Valley's total acreage declined by 5% compared to 1976. In 1978, total acreages fully recovered -- 9% higher than in 1977 and 7% higher than the pre-drought period.

Irrigated crop and pasture acreage remained above the pre-drought average throughout the 1976-77 drought. In 1977, the rate of acreage increase declined somewhat, but 1978 brought a return to the upward trend.

Total acreage of barley and wheat, the two major dryland crops, declined substantially during the 1976-78 period. In 1977, dryland wheat acreage fell to 34% of the pre-drought average. By contrast, barley acreage was lower than the pre-drought average, but gradually increased from 1976-78.

Table 19

MAJOR CROP ACREAGE
CENTRAL VALLEY - CALIFORNIA
1973-75, 1976, 1977, and 1978

Crop Group/Crop	1976	1977	1978
IRRIGATED CROPS	---Acreage as Percent of 1973-1975 Average---		
Fruit & Nut Crops			
Grapes, raisin	101	102	101
Grapes, table	101	99	97
Grapes, wine	158	163	165
Grapes, Subtotal	117	118	118
Almonds	112	118	133
Walnuts	110	114	118
Oranges	106	106	106
Peaches	96	96	89
Prunes	96	97	97
Olives	108	119	140
Plums	107	113	118
Apricots	95	100	93
Pears	101	109	109
Figs	96	82	85
Total	110	113	116
Vegetable Crops			
Tomatoes, processing	94	109	97
Melons, all	84	86	121
Potatoes, Irish	105	86	70
Lettuce	112	116	111
Beans, lima	57	80	107
Total	92	101	100
Field Crops			
Cotton	106	125	143
Hay, alfalfa	92	84	77
Barley	121	114	105
Rice	90	68	109
Wheat	133	126	119
Corn, grain	118	101	114
Sorghum, grain	87	34	56
Sugarbeets	118	79	81
Safflower	36	59	91
Corn, silage	126	99	95
Beans, dry edible	95	104	143
Seed, alfalfa	94	102	141
Total	103	97	108
Irrigated Crops Total	104	101	109
DRYLAND CROPS			
Barley	73	82	89
Wheat	108	34	39
Total	90	60	66
GRAND TOTAL	103	98	107

Source: 1. CCLRS. Vegetable Crops and Field Crops reports, 1976-1978.
2. County Agr. County Commissioners reports/Central Valley, 1973-1978.

Crop yields during the drought were adversely affected for some crops, but other crops experienced yields higher than their pre-drought average (Table 20). In 1976, crop yields for 18 of the 28 irrigated crops were higher than the pre-drought average. In that year, both dryland barley and dryland wheat yields were higher than their pre-drought yields. The expectation that the drought would lower 1977 yields was not realized to any remarkable degree. In 1977, crop yields for 24 of the 28 irrigated crops were higher than the pre-drought average. Yield levels for the two major dryland crops were mixed. Dryland wheat yields were only 63% as high as the pre-drought average. By contrast, dryland barley yields were 106% of the pre-drought average.

Crop yields for irrigated crops in 1978 were very disappointing when compared to earlier years. Olives was the only irrigated crop with a higher yield than in 1977. By contrast, dryland crop yields for wheat and barley were higher. Dryland wheat yields returned to the pre-drought average. Dryland barley yields were 28% higher than the pre-drought average.

The prices received by farmers for the major crops were generally quite favorable during the 1976-78 period (Table 21). In 1976, prices for seven of the fourteen major fruit and nut crops were above the pre-drought average. In 1977, 11 of these 14 fruit and nut crops were higher than their respective pre-drought average price. In 1978, olives was

Table 20

MAJOR CROP YIELDS
CENTRAL VALLEY - CALIFORNIA
1973-75, 1976, 1977, and 1978

Crop Group/Crop	1976	1977	1978
	---Yield as Percent of 1973-1975 Average---		
Fruit & Nut Crops			
Almonds	120	111	62
Walnuts	100	109	86
Grapes, raisin	84	90	70
Grapes, table	91	103	80
Grapes, wine	79	89	90
Peaches, all	100	115	109
Prunes	98	107	92
Pears	119	105	97
Plums	87	106	102
Oranges, all	98	106	92
Olives	111	55	144
Apricots	94	107	101
Vegetable Crops			
Lettuce	105	114	110
Melons, all	137	126	95
Potatoes, Irish	109	123	106
Tomatoes, processing	91	101	94
Field Crops			
Cotton	107	103	59
Wheat, irrigated	116	115	104
Wheat, dryland	201	63	100
Barley, irrigated	104	108	89
Barley, dryland	129	106	128
Rice	95	105	95
Dry edible beans	93	97	81
Sugarbeets	112	101	96
Corn, grain	107	114	109
Corn, silage	104	106	98
Sorghum, grain	104	103	97
Hay, alfalfa	110	108	100
Seed, alfalfa	110	117	52
Safflower	102	138	96

Source: 1. CCLRS. Vegetable Crops and Field Crops reports, 1976-1978.

2. County Agricultural County Commissioners reports for Central Valley counties, 1973-1978.

Table 21

MAJOR CROP PRICES
CENTRAL VALLEY - CALIFORNIA
1973-75, 1976, 1977, and 1978

Crop Group/Crop	1976	1977	1978
	---Price as Percent of 1973-1975 Average---		
Fruit & Nut Crops			
Grapes, raisin	113	138	167
Grapes, table	125	155	197
Grapes, wine	91	117	140
Grapes, all	107	134	161
Almonds	73	95	158
Walnuts	127	148	261
Oranges	102	122	200
Peaches	100	106	127
Prunes	95	115	149
Olives	85	104	48
Plums	130	107	134
Apricots	93	97	128
Pears	82	88	144
Figs	81	134	145
Vegetable Crops			
Tomatoes, processing	101	115	114
Melons	130	124	120
Potatoes, Irish	78	99	124
Lettuce	115	118	166
Beans, lima	100	119	123
Field Crops			
Cotton	134	111	125
Hay, alfalfa	128	103	105
Barley	100	88	95
Rice	68	90	111
Wheat	94	80	76
Corn, grain	82	72	83
Sorghum, grain	81	72	80
Sugarbeets	66	78	76
Safflower	96	97	91
Beans, dry edible	97	105	93
Seed, alfalfa	123	108	147

Source: 1. U.S. Dept. of Agriculture, Agricultural Statistics, 1973-1979.

2. CCLRS, Field Crops, Vegetable Crops, and Fruit and Nut Crops annual reports, 1973-1979.

the only fruit and nut crop below the pre-drought price. For the four major vegetable crops, prices were generally above the pre-drought average. The exception was Irish potatoes in 1976 and 1977. Field crop prices were quite variable during the 1976-78 period. Three of the eleven field crops were also above their pre-drought average -- cotton, alfalfa hay, and alfalfa seed.

The total value of production for major Central Valley crops was above the pre-drought average for all three years in the 1976-78 period (Table 22). Production values for irrigation crops were higher for all three years. By contrast, production values for the two dryland crops were slightly higher in 1976, but were lower in both 1977 and 1978.

The dollar value of fruit and nut crops trended sharply upward during the 1976-78 period. Compared to the pre-drought period, total fruit and nut values were 103%, 134%, and 150% for the years 1976, 1977, and 1978 respectively.

The total value of vegetable crops was the highest in 1977, at 126% of the pre-drought average. The 1976 value was the same as the pre-drought average. The 1978 value was 114% of the pre-drought average.

The total production value of field crops was higher than the pre-drought average for all three years. The best year was 1977, when the total value was 116% of the pre-drought average. The 1978 value was 115% of the pre-drought

Table 22

TOTAL VALUE OF PRODUCTION
CENTRAL VALLEY - CALIFORNIA
1973-75, 1976, 1977, and 1978

Crop Group/Crop	1976	1977	1978
IRRIGATED CROPS	---Value as Percent of 1973-1975 Average---		
Fruit & Nut Crops			
Grapes, raisin	95	126	117
Grapes, table	115	158	152
Grapes, wine	113	169	208
Grapes, Subtotal	103	143	148
Almonds	97	125	128
Walnuts	139	185	265
Oranges	106	137	194
Peaches	96	117	123
Prunes	89	119	134
Olives	101	69	96
Plums	122	128	160
Apricots	83	103	120
Pears	98	101	154
Figs	45	100	110
Total	103	134	150
Vegetable Crops			
Tomatoes, processing	86	127	105
Melons, all	148	133	138
Potatoes, Irish	89	105	91
Lettuce	135	156	202
Beans, lima	49	111	115
Total	100	126	114
Field Crops			
Cotton	154	143	106
Hay, alfalfa	130	94	81
Barley	126	107	83
Rice	58	64	78
Wheat	144	116	124
Corn, grain	103	83	103
Sorghum, grain	74	25	43
Sugarbeets	88	62	59
Safflower	35	79	80
Beans, dry edible	86	105	107
Seed, alfalfa	107	108	88
Total	113	100	89
Irrigated Crops Total	108	116	115
DRYLAND CROPS			
Barley	95	76	108
Wheat	113	17	39
Total	106	41	67
GRAND TOTAL	107	115	114

average. The 1976 value was 108% of the pre-drought average.

Farm Income

A comparison of the State's gross and net farm income reveals that there was an upward trend during the 1976-78 period (Table 23). Both gross and net farm income increased by about 7% from 1975-76. In comparing 1976 to 1977, net farm income rose by 5%. The 1977 gross farm income and expenses set records, with the net farm income level only exceeded by that of 1974. In 1978, gross income, production expenses, and net income set records for the State of California. Net farm income was $3.09 billion, up 22% from 1977, and 11% higher than the previous high net income value realized in 1974.

Table 23

FARM INCOME
Realized Gross and Net Income
California
1973-1978

Year	Gross Farm Income	Farm Production Expenses	Net Farm Income a/
	Million Dollars		
1973	7,229	5,284	2,453
1974	8,613	6,319	2,778
1975	8,497	6,523	2,436
3-Year Average	8,113	6,042	2,556
1976	9,079	6,952	2,455
1977	9,341	7,301	2,525
1978	10,369	7,785	3,090

a/ Realized net income plus or minus the value of net changes in farm inventories. It agrees with the concepts used in the national income estimates of the U.S. Dept. of Commerce, where it is termed farm proprietors' income.

Source: California Crop and Livestock Reporting Service, California Farm Income, released Sept. 18, 1979.

LESSONS LEARNED FROM THE CALIFORNIA DROUGHT

The California drought was the most pervasive and costly in the State's history. Despite the potential for extensive agricultural losses in the Central Valley, a number of timely actions on the part of State and Federal officials, resource agencies, and individuals caused the drought effects to be minimized. The results of these actions turned 1977 from a potentially lean year into one which had the second highest net farm income in the State's history.

The Western Governors' Policy Office has documented lessons which were learned from dealing with the mid-seventies drought (6). The purpose of this summary is to highlight the lessons learned as a result of the FAS efforts to assist the DTF in taking appropriate policy measures to mitigate the economic effects on the State's agricultural sector.

The FAS was operating in a fast-moving resource situation which had no modern historical precedent. The committee was faced with two major problems -- a limited data base and a lack of information regarding ongoing actions which were being taken by agencies and individual farmers to offset the drought's effects.

The FAS had the advantage of access to an existing water-resource related analytical system for the San Joaquin Valley. They had the further advantage of having committee

members who were fully familiar with information from their individual agencies.

The major disadvantages facing the FAS were sixfold: 1) the Central Valley data base was limited to irrigated agriculture and was outdated (four years old) for the San Joaquin Valley and non-existent for the Sacramento Valley; 2) the relationship between cropland and rangeland yields and drought conditions was not known; 3) there were no available statistics on the number of new irrigation wells being drilled or old wells brought back into service; 4) the extent to which farmers were modifying their conventional farming practices was not known; 5) statistics concerning farmers' planting intentions were available at the statewide level, but there was no way to disaggregate the figures to the regional level, e.g., the Central Valley; and 6) crop price prediction procedures were not available.

Despite these limitations, the FAS was ultimately successful in forecasting the extent to which the drought would affect the Central Valley and the State of California as a whole. The early FAS analysis followed the pattern of others in generally overestimating the drought's impacts. By May 1977, the FAS was able to acquire enough data to evaluate the drought in the context of water resource adjustments which were in the process of taking place.

The California drought is a good example of the extent to which individuals and agencies can respond to a crisis

situation. There appear to have been three distinct stages in attitudes regarding the drought as it progressed: 1) initial denial of its existence and false hopes that the problem would somehow go away -- this covers the period from late 1975 - late 1976; 2) full recognition of the drought coupled with an overreaction to its consequences and over-estimation of its effects -- the period from early 1977 - late summer 1977; and 3) realistic reappraisal of the drought as a resource problem able to be overcome by individual and cooperative action -- the period from fall 1977 until the drought was broken in February 1978.

SUGGESTIONS FOR FUTURE DROUGHT STUDIES

The availability of an accessible, ongoing analytical capability of the agricultural economy, coupled with an up-to-date information network, is probably the key ingredient for conducting future drought analyses. An ideal analytical system would be able to provide an assessment at both the statewide and regional levels of disaggregation. The analytical capability should include the evaluation of the agricultural commodity price effects of alternative farm production and resource availability scenarios. An evaluative procedure, such as input-output analysis, should also be developed so that secondary effects such as employment and sales can be estimated.

In the area of farmers' future planting intentions, major improvement is needed in existing procedures to permit regional differentiation, as well as irrigated and dryland crop separation. Currently California provides only statewide and crop total acreage estimates.

The frequency of data collection for ground water pumping should be increased to include more detailed information. Current data is limited to the number of new wells which have been registered with the State of California in any given month. Ground water data collection procedures need to be expanded to include the extent to which older wells are still being utilized, the water yield for agricultural purposes

from wells, and the average pumping lifts.

Cooperative research should be incorporated to evaluate the extent to which crops can utilize less water, as well as higher salinity water, during drought periods. This research should include an evaluation of the extent to which crop yields are depressed not only during the drought, but in subsequent years. An economic evaluation of alternative water conserving techniques should also be undertaken.

APPENDIX A

SUMMARY HISTORY

OF

THE CALIFORNIA DROUGHT

The California drought probably began in May 1975 with the onset of below normal precipitation. There was still little cause for concern because reservoirs were filled to normal and ground water supplies appeared to be adequate. October, November, and December in the fall of 1975 were record dry months. The below normal precipitation continued until early 1978 when an extended period of heavy precipitation caused the drought to be broken. Let us now review the way in which the drought unfolded.

1976 Water Year

In this year, precipitation in the Central Valley Basin was from 20-60% of normal. With the exception of the extreme northwestern part of the State, the northern 1/3 of California received less than 60% of normal precipitation.

Inflows into the major water storage reservoirs serving the Central Valley were significantly reduced. Total inflow into the three major CVP reservoirs -- Shasta, Claire Engle, and Folsom -- amounted to only 5.0 MAF, compared to a normal year inflow of 9.5 MAF. Inflow into the SWP reservoirs was also quite low. Oroville, the major SWP reservoir, with a capacity of 3.5 MAF, received only 40% of average inflows in the 1976 water year. The area served by the San Joaquin River system -- Friant Dam and the Madera and Friant-Kern Canals -- was the most adversely affected of any irrigation water service area. Precipitation and runoff were the third lowest in more than 100 years.

State water officials discussed the possibility of reduced deliveries with agricultural contractors early in calendar year 1976. Since many water users were already committed to growing certain crops by then, the contractors responded that they wanted full deliveries while water was available (9). The SWP proceeded to set a water delivery record of 2.07 MAF, exceeding by 100,000 acre-feet the record set in the 1975 water year.

CVP officials reduced their agricultural deliveries by 1 MAF. The area experiencing reduced deliveries was confined to the east side of the San Joaquin Valley. There were some agricultural contractors there who did not have firm CVP delivery contracts. CVP officials estimated on the basis of historical experience that 1977 would probably not be as dry as 1976 had been.

At the end of the 1976 water year, carryover storage for both the SWP and CVP was below normal. SWP carryover was only 60% of normal. The CVP was slightly better off with carryover storage at 65% of normal.

The number of new water well drilling reports filed with the DWR increased rather substantially in 1976. There were 11,200 wells reported to have been drilled -- 2,900 more than in 1975. This new well drilling, coupled with increased pumping from existing wells, largely offset reductions in surface water supplies, particularly on the east side of the San Joaquin Valley.

In 1976, 28 of California's 58 counties were declared disaster areas. In the Central Valley, the disaster counties extended in the north to Kings and in the south to Tulare County. Within the Central Valley, four Sacramento Valley counties were not declared disaster areas -- Butte, El Dorado, Placer, and Yuba. There were only two San Joaquin Valley counties excluded from the disaster area designation -- Kern and Mariposa.

1977 Water Year

As the 1977 water year progressed, it became evident to Federal and State officials that another drought year was unfolding. Northern and central portions of the State set all-time records for low precipitation and runoff. Across the State, 22 of the 26 major streams set new record lows for runoff volumes.

Inflows to reservoirs were far below normal. The Oroville Reservoir, the primary SWP storage facility, received record low inflows that were less than 25% of normal. The CVP reservoirs received inflows of only 3.67 MAF, 32% of normal and 128,000 acre-feet less than the previous low of water year 1924.

Surface water deliveries to agricultural customers in the Central Valley plummeted. SWP total water deliveries decreased 53% from the previous year, with agricultural deliveries declining by about 580,000 acre-feet. CVP agri-

cultural water deliveries decreased to 3.11 MAF, or about 45% of normal. Delivery volumes would have been even lower if interagency water exchange agreements among Federal, State, and local agencies had not been successfully executed.

At the end of the 1977 water year, carryover reservoir storage for all Central Valley facilities was only 36% of normal. The CVP carryover storage was only 1.24 MAF, compared to a normal carryover of 6.30 MAF. The SWP carryover was also much smaller at 0.92 MAF, which was much lower than the normal 2.46 MAF.

The number of new well drilling reports filed with the DWR increased very substantially again. The DWR reported that 20,290 new wells were drilled in 1977. This was 9,080 more wells than were drilled in 1976 -- an increase of 80%.

The 1977 water year was the worst drought year on record for the State of California. As a result of continued drought conditions, 47 of the 58 counties of California were declared disaster areas. All of the Central Valley counties were designated disaster areas.

1978 Water Year

Beginning in December 1977, and continuing through January 1978, heavy rain and snow fell on the State. The precipitation was enough to cause a return to normal water conditions throughout the State.

Water storage reservoirs serving the Central Valley's farmers were filled to above-normal levels by mid-January 1978. By the end of the 1978 water year, SWP storage was the highest since the SWP had become fully operational in the 1973 water year. CVP reservoirs also returned to above normal storage conditions by the end of the year.

With the return to normal surface water conditions, the reported number of new well drillings declined for the first time since 1975. In 1978, 18,520 new wells were drilled, down about 10% from 1977.

APPENDIX B

DESCRIPTION OF SAN JOAQUIN VALLEY BASIN MODELS

Background

Two basinwide linear programming models, for the San Joaquin Basin and the Tulare Basin respectively, were developed by the USDA California River Basin Planning Staff (11, 25). These two models were developed during the San Joaquin Valley Basin Study which was completed in 1977. The models were used to analyze the present and future impacts of deteriorating drainage conditions in the San Joaquin Valley. The two basin models are further subdivided into an east and west side to evaluate the differing resource conditions and problems in these two areas of the San Joaquin Valley.

These two analytical models contain specific cropping activities and on-farm production costs for each crop on a specific soil group basis. Twenty-nine crops are considered in each model. There are 25 single crops, 3 double crops, and irrigated pasture. These crops are further differentiated on the basis of adequately, partially, or poorly drained condition for both the west and east side of each basin. There are also 18 different soil groups. The models each have about 1,500 activities. Technological coefficients for each model activity are specified on an annual per acre basis. These coefficients include yields, applied water requirements, harvest and nonharvest labor, nitrogen fertilizer, and gas and diesel fuel use. The objective function maximizes net agricultural crop returns to land, management, and risk, subject to the availability of land resources by

soil group, drainage condition, location (east or west side), the availability of surface and ground water for irrigation, labor, and cropping pattern restrictions. A feature which has been added to the model is termed the average yield reality restraint. This requirement prevents crop production from concentrating on the highly productive and profitable soil groups. The effect of this condition is that model solutions are very similar to actual conditions.

The two models were used in the San Joaquin Valley Basin Study in several ways. First, they were used in the evaluation of base year (1972) conditions with respect to the estimated effects of adding USDA drainage projects. Second, they were used in future analysis, including the target years 1985 and 2000, under several alternative resource availability projection scenarios, and with and without the USDA drainage projects.

Drought Study Application

The San Joaquin and Tulare Basin models were revised by the FAS several times in 1977 in an effort to analyze alternative drought scenarios. There were three major revisions which were made: 1) the technological coefficients were updated to reflect 1977 drought and no-drought conditions, 2) costs and prices were revised to a 1977 basis, and 3) resource availability levels were revised to reflect drought conditions.

There were three major sets of drought analyses which were conducted by the FAS as the study progressed. The first analysis was conducted in March 1977. Subsequent analyses were conducted in April and May 1977 in an effort to model the rapidly changing water resource conditions as the drought progressed.

REFERENCES

1. Englebert, Ernest A., Editor. California Water Planning and Policy: Selected Issues. California Water Resources Center, Univ. of California, Davis. June 1979.

2. Fritts, Harold C. and Geoffrey A. Gordon. Annual Precipitation for California Since 1600 Reconstructed from Western North American Tree Rings. Laboratory of Tree-Ring Research, Univ. of Arizona. July 1980.

3. Horner, Gerald L. and Daniel J. Dudek. An Analytical System for the Evaluation of Land Use and Water Quality Policy Impacts upon Irrigated Agriculture. Dept. of Agricultural Economics, Univ. of California, Davis. Working Paper No. 79-15. 1979.

4. Howitt, Richard E. "Is Overdraft Always Bad?" Paper presented at the 12th Biennial Conference on Groundwater, held in Sacramento, California on Sept. 20-21, 1979.

5. Howitt, Richard E., William D. Watson, and Carole F. Nuckton. Efficiency and Equity in Management of Agricultural Water Supplies. Univ. of Calif. Div. of Agr. Sciences. Bulletin 1892. March 1979.

6. Institute for Policy Research, Western Governor's Policy Office. Managing Resource Scarcity: Lessons from the Mid-Seventies Drought. A report to the Governors on Drought Management. 1978.

7. Lawrence Berkeley Laboratory. Energy Analysis Program. Energy and Environmental Division. Effects of the Drought on California Electricity Supply and Demand. LBL-6356. June 1977.

8. __________. Potential Electricity Impacts of a 1978 California Drought. LBL-6871. January 1978.

9. __________. Energy and Water Use in Irrigated Agriculture During Drought Conditions. LBL-7866. June 1978.

10. Maass, Arthur and Raymond L. Anderson. ... and the Desert Shall Rejoice: Conflict, Growth, and Justice in Arid Environments. Cambridge, Mass.: MIT Press. 1978.

11. McKusick, Robert B. "Multiple Objective Planning and Evaluation as Related to Drainage Problems: A Linear Programming Model for Agriculture." Paper presented to the 12th Annual Meeting of the California Irrigation Institute held in Fresno, Calif. on Feb. 19-20, 1974.

12. State of California. Agriculture and Services Agency. Dept. of Food and Agriculture. Governor's Drought Emergency Task Force. Projected 1977 California Agricultural Drought Report. August 1, 1977.

13. State of California. Office of the Governor, Department of Water Resources, and Department of Food and Agriculture. Proceedings of the Governor's Drought Conference. March 1977.

14. State of California. The Resources Agency. Department of Water Resources. The California Water Plan: Outlook in 1974. DWR Bulletin No. 160-74. Nov. 1974.

15. _________. Special Report on Dry Year Impacts in California. Feb. 1, 1976.

16. _________. Water Conservation in California. Bulletin No. 198. May 1976.

17. _________. The California Drought - 1976. May 1976.

18. _________. The California Drought - 1977: An Update. Feb. 15, 1977.

19. _________. The Continuing California Drought. August 1977.

20. _________. The 1976-1977 California Drought: A Review. May 1978.

21. _________. The California State Water Project - 1977 Activities and Future Management Plans. Bulletin 132-78. Oct. 1978.

22. _________. The California State Water Project - 1978 Activities and Future Management Plans. Bulletin 132-79. Nov. 1979.

23. _________. Measuring Economic Impacts: The Application of Input-Output Analysis to California Water Resource Problems. Bulletin 210. March 1980.

24. U.S. Comptroller General. California Drought of 1976 and 1977 -- Extent, Damage and Governmental Response. CED 77-137. Oct. 19, 1977.

25. U.S. Dept. of Agriculture. California River Basin Planning Staff -- Soil Conservation Service, Forest Service, and Economic Research Service in cooperation with Calif. Dept. of Water Resources. San Joaquin Valley Basin Study, California. Final Report. Nov. 1977.

26. U.S. Dept. of Agriculture. Economic Research Service. 1977 Drought Analysis for Irrigated Agriculture: San Joaquin Valley Basin, California. Interim Report. March 31, 1977.

27. U.S. Dept. of Agriculture. Economics, Statistics, and Cooperatives Service. Agricultural Water Management Analysis for the Central Valley of California: Projected 1978. Draft Report. Sacramento Valley Basin Study, Special Study No. V, Report No. 1. Feb. 28, 1978.

28. __________. Agricultural Water Management Analysis for the Central Valley of California: Projected 1978. Draft Report. Sacramento Valley Basin Study, Special Study No. V, Report No. 2. April 30, 1978.

29. __________. Agricultural Water Management Analysis for the Central Valley of California: Projected 1978. Draft Report. Sacramento Valley Basin Study, Special Study No. V, Report No. 3. July 1978.

30. U.S. Dept. of Interior. Bureau of Reclamation. Mid-Pacific Region. Central Valley Project, California: Water Operations in 1976 -- A Dry Year. Dec. 1976.

31. __________. Central Valley Project, California: Water Operations in 1977 -- The Second Dry Year and Premliminary Plans for 1978. Dec. 1977.

32. University of California. Division of Agricultural Sciences. Agricultural Issues Task Force. Agricultural Policy Challenges for California in the 1980's. Special Publication 3250. Oct. 1978.

33. Westlands Water District. Irrigation Management Service. Annual Reports for the years 1976-1978.

34. Willey, W. R. Z. "Ground Water in the California Water Quandry." Paper presented at the 11th Bienniel Conference on Ground Water, held at Fresno, Calif. on Sept. 15, 1977.